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COMMENTS ON SOME SOUTHERN AUSTRALIAN FORAMINIFERA AND DESCRIPTION OF THE NEW GENUS *PARREDICTA*

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Summary

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The distribution and relationship of 20 benthic foraminiferal genera from southern Australia are reviewed, and ranges of some stratigraphically useful species are revised. Among these, *Crespinella*, *Crespinina*, *Hofkerina*, *Maslinella* and *Wadella* are endemic to the Australian-New Zealand region. Others contain species which are either endemic or cosmopolitan forms or those migrating into the region at various times. The new genus *Parredicta* is described to include two endemic species, *Planulina kalimnensis* Parr (early Miocene-late Pliocene) and *Valvulineria porifera* Parr (Pleistocene-Recent).

KEY WORDS: benthic foraminifera, Eocene, Oligocene, Miocene, southern Australia, *Parredicta*, new genus.

Introduction

Foraminifera are single-celled protozoans widely employed in stratigraphy and marine geology for age-dating and palaeoenvironmental interpretation. Howchin's (1889, 1891) work, which appeared in this *Transactions*, laid the foundation for surveying local foraminiferal assemblages. Foraminiferal studies in the early part of this century in Australia were cultivated particularly by W. J. Parr. Like his New Zealand counterpart H. J. Finlay, Parr published many papers on recent and fossil foraminifera and supplied numerous specimens for J. A. Cushman to describe (Glaessner 1950). Recent and modern students, including Carter (1958, 1964), Quilty (1974, 1977, 1981, 1982--mainly small benthics) and Chaproniere (1984--larger benthics), tend to emphasize the foraminiferal biostratigraphic application, as well as lineage classification. Systematic treatments of southern Australian foraminifera, however, have not yet reached the standard of Hornibrook *et al.* (1989) from New Zealand. Local marine sequences have been correlated with standard biostratigraphy (e.g. McGowran 1979), but the correlation lacks cross-reference to the geomagnetic record, and the range of many species is not well defined. Confusion over synonyms adds difficulties to any attempt for systematic compilations.

As a prelude to such a compilation, this paper summarizes current knowledge of some important Cenozoic taxa based on material from several southern Australian basins. The records of these taxa, as reported elsewhere (Loeblich & Tappan 1987), are revised. The new genus *Parredicta* is proposed to accommodate *Valvulineria porifera* Parr and *Planulina kalimnensis* Parr.

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The Material

The late Eocene to early Oligocene samples were taken mainly from two localities: Maslin Bay on the southwest coast of Adelaide, South Australia and Browns Creek, Aire District in Victoria (Fig. 1). The Maslin Bay sequence has been described and discussed in great detail by McGowran & Beecroft (1986) and McGowran (1990), and both sections by McGowran *et al.* (1992). The Lakes Entrance oil shaft section from Gippsland Basin spanning the late Oligocene-late Miocene was the focus of our study of faunal overturn and ecostratigraphy (McGowran & Li 1993, 1995; Li & McGowran 1995), and thus forms part of the material here. We also examined 29 samples from the early middle Miocene Morgan-Cadell section from the Murray Basin (Ludbrook 1961). As well, we refer to the material during a recent biofacies study of dredged samples from the Lacepede Shelf (Li *et al.* 1995). Other material includes random samples from Castle Cove (near Browns Creek) and WMC core 703 in Kingston, South Australia. Relevant type specimens deposited in the South Australian Museum and in the Department of Geology & Geophysics, The University of Adelaide, were also examined. Several scanning photographs, originally taken by J. M. Lindsay on material from the South Australian Department of Mines and Energy, are also reproduced.

Localities are shown in Fig. 1, and ranges of taxa discussed in Fig. 2. The generic references to these taxa refer to Loeblich & Tappan (1987). Appendix 1 alphabetically lists all genera and species mentioned in this report.

Systematic Remarks

Order Foraminiferida Eichwald, 1830
Suborder Rotaliina Delage & Hérouard, 1896
Family Almaenidae Myatlyuk, 1959
Genus *Almaena* Samoylova, 1940

Synonymy and Type species: see Loeblich & Tappan 1987, p. 622.

Remarks

In their compilation of *Almaena*, Loeblich & Tappan (1987) apparently overlooked its record in southern Australia. From the Gippsland Basin, Carter (1964) described *Almaena gippslandica* (Fig. 4, 1a, b), a form undoubtedly belonging in this genus.

Carter (1964) correctly indicated that *Almaena gippslandica* was restricted to the region, as it has to date never been reported from any other localities. It ranges from 347 m - 320 m in the Lakes Entrance section, in an interval equivalent to planktonic foraminiferal Subzone N4b, earliest Miocene (Li & McGowran 1995).

It is not known whether *A. gippslandica* is synonymous with any European taxon or whether it represents a migratory species from Paratethys where the genus first evolved in the later Eocene (Loeblich & Tappan 1987).

Family Asterigerinatidae Reiss, 1963
Genus *Asterigerinella* Bandy, 1949

Synonymy and Type species: see Loeblich & Tappan 1987, p. 606.

Remarks

According to Loeblich & Tappan (1987), this genus differs from the similarly stellate *Asterigerina* d'Orbigny in having a flattened lenticular test and a high aperture. The wall is papillate on both sides of the test, in contrast to the smooth surface in *Asterigerina*. Loeblich & Tappan (1987) found the type species *A. gallowayi* from Alabama to be the only record.

Howchin's (1891) taxon, *Truncatulina margaritifera* var. *adelaidensis*, bears every feature of *A. gallowayi* and must be a form of *Asterigerinella*. Lindsay (1969, pl. 2, fig. 2, 4) illustrated a topotype of *A. adelaidensis* and Lindsay (1985, p. 203, as *Asterigerina*) indicated that the species ranged from the top of South Maslin

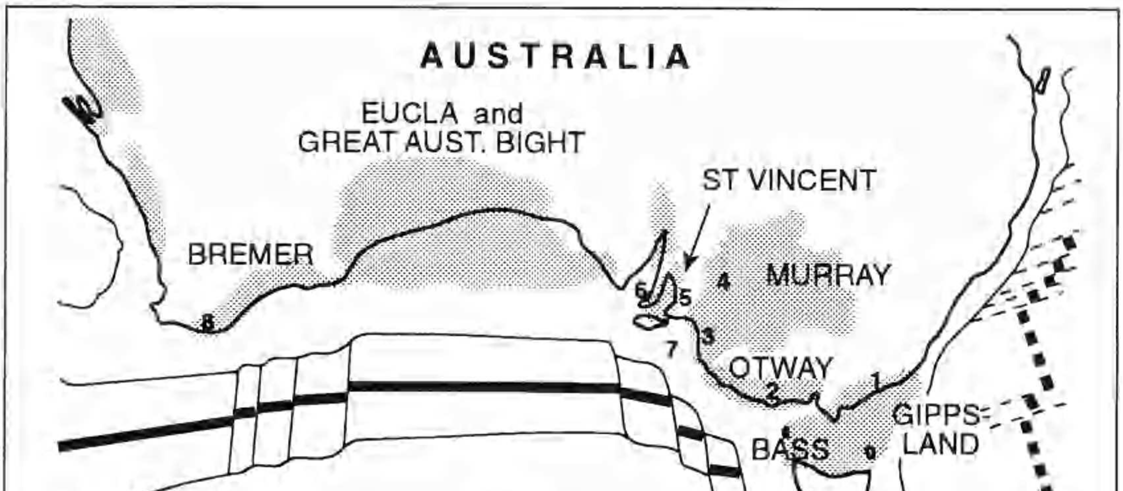

Fig. 1. Southern Australia in the later middle Eocene, showing major Tertiary sedimentary basins (adapted from Falvey & Mutter 1981). It was not until this time that sedimentation became widespread along the southern margin. Numbers 1-7 are section localities: 1. Lakes Entrance, Victoria. 2. Browns Creek and Castle Cove, Victoria. 3. WMC core 703, Kingston, South Australia. 4. Morgan and Cadell, Murray Basin, South Australia. 5. Maslin Bay (Tortachilla, Blanche Point), South Australia. 6. Yorke Peninsula (Port Vincent), South Australia. 7. Lacepede Shelf, South Australia. 8. Nanarup, Western Australia.

Sand to Perkana Member of the Blanche Point Formation, Zones P13-P15 in modern biostratigraphical correlation (McGowran *et al.* 1992). This view is confirmed again here in our recent observations.

As illustrated in Fig. 4, 2, 3, *A. adelaidensis* can be differentiated from the slit-apertured *A. gallowayi* by its almost circular aperture.

Family Bronnimanniidae Loeblich & Tappan, 1984
Genus *Bronnimannia* Bermúdez, 1952

Synonymy and Type species: see Loeblich & Tappan 1987, p. 563.

Remarks

Forms of *Bronnimannia* are rare in southern Australia, although the closely related *Discorbinella* and *Planulina* have been widely reported (Parr 1950; Carter 1964; Quilty 1977). Our record of *B. haliotis* from Cadell Marl section (Zones top N8 to lower N9, early middle Miocene) thus confirms the occurence of the genus in the region. Quilty (1994, pers. comm.) recently informed us that he has found similar forms in the Swan River estuary, Western Australia.

Bronnimannia haliotis (Fig. 4, 4a, b) is similar to the type species *B. palmerae* in the auricular biconcave test. Unlike the latter taxon, however, the South Australian species is much flatter and lacks a distinct marginal keel. The strongly concave, evolute (ventral) side is coarsely perforate, with limbate, imperforate sutures. All these suggest that the illustrated form is a distinct, perhaps endemic, species.

Family Cibicididae Cushman, 1927
Genus *Cibicides* de Montfort, 1808

Synonymy and Type species: see Loeblich & Tappan 1987, p. 582.

Remarks

The cibicidids are one of the most abundant and diverse foraminiferal groups found in many parts of southern Australia. This group includes trochospiral forms with an extraumbilical aperture which may extend around the periphery and onto the spiral (dorsal) side. With these features, *Cibicides*, *Cibicidoides* and *Heterolepa* may be lumped as cibicidids in a classical study of biofacies (e.g. Hornibrook *et al.* 1989). Although Loeblich & Tappan (1987) demonstrated different hyaline walls between *Cibicides* and *Cibicidoides* and classified them in two different superfamilies, these two genera are always associated in a faunal community and some of their species show transitional characters, particularly in the flat to convex dorsal side.

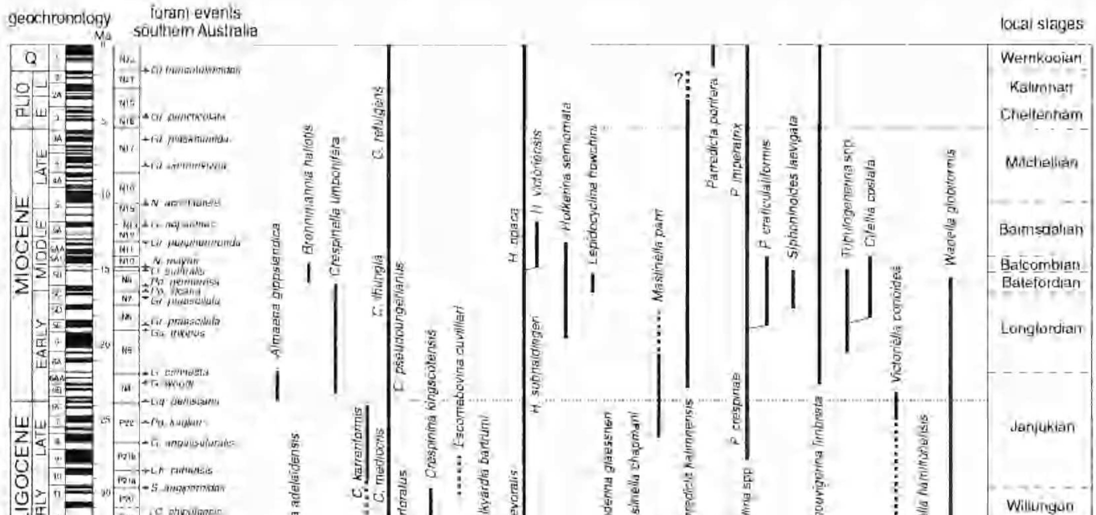

Fig. 2. Ranges of the taxa discussed. Geochronology after Cande & Kent (1992) and N/P zones after Berggren *et al.* (1985a, b). Correlation of local planktonic foraminiferal data and regional stages follows McGowran *et al.* (1971), Heath & McGowran (1984), and McGowran & Li (1993, 1994).

Quilty (1982, p. 10) listed over 20 cibicidid species known from the Tertiary of southern Australian and New Zealand. Together with the biconvex allied *Cibicidoides*, the planoconvex genus *Cibicides* averages 20% - 50% of total fauna in most samples. Typical cibicidid forms include *Cibicides ihungia* (Fig. 4, 7, 8), *C. mediocris* (Fig. 4, 9, 10), *C. vortex* (Fig. 4, 6a, b), *Cibicidoides perforatus* (Fig. 4, 11) and *C. pseudoungerianus* (= *Cibicides neoperforatus*) (Fig. 4, 12, 13). The evolution of *C. pseudoungerianus* from *C. perforatus* was in the late Eocene, by a reduction of coarse perforations from both sides (on *C. perforatus*) and restriction to the spiral side of the test. The stratigraphically most useful species is *C. karreriformis* Hornibrook, occurring in the Oligocene (Fig. 2). Other previously described species, such as *C. subhaidingeri* and *C. opacus*, are now placed in the genus *Heterolepa* (see below).

Three cibicidids characterising the modern biofacies on Lacepede Shelf, South Australia, are *Cibicides refulgens* (Fig. 4, 5), *C. mediocris* and *Cibicidoides pseudoungerianus* (Li *et al.* 1995).

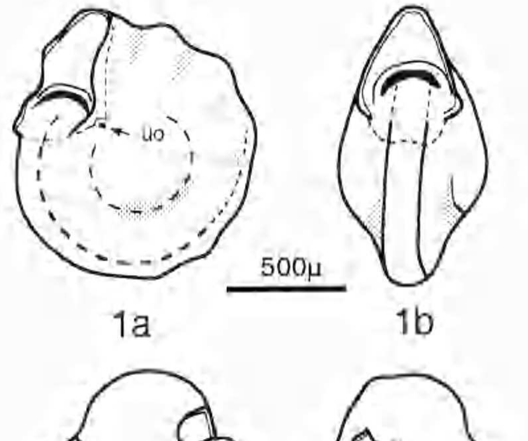

Fig. 3. 1a, b. *Crespinella umbonifera*: sketches of the holotype of ?*Operculina umbonifera* Howchin & Parr (1938) (see also the scanning micrographs in Fig. 4, nos. 14a, b). 2a, b. *Maslinella chapmani* Glaessner & Wade (1959): sketches of the holotype. Both types are deposited in the South Australian Museum. Note that the final chamber on both tests is missing, but umbilical openings (uo) are present.

Family Eponididae Hofker, 1951
Genus *Crespinella* Parr, 1942

Synonymy and Type species, see Loeblich & Tappan 1987, p. 579.

Remarks

Parr (1942) erected the early Miocene taxon ?*Operculina umbonifera* Howchin & Parr as the type species of his genus *Crespinella*, separating this simple form from similarly planispiral but internally complex *Operculina*.

Crespinella was monospecific until Quilty (1980) added to it another species, *C. parri*, with a low trochospiral (other than planispiral) coiling. The overall morphological similarity between *C. umbonifera* and *C. parri* led Quilty (1980) to imply that both *C. parri* and *C. umbonifera* are phylogenetically related, with *C. parri* being the predecessor. Loeblich & Tappan (1987), however, rejected this statement on the basis of the distinct trochospiral coiling and supplementary sutural openings in Quilty's species. Such confusion over the generic status of *C. parri* needs to be clarified.

Li has inspected the holotype of *C. umbonifera*, which was made available from the South Australian Museum, and found that it also possesses an opening on the umbilical side (Fig. 3, 1a, b; Fig. 4, 14a, b). It is an incomplete specimen with the final chamber missing, and a small opening can be observed at the base of the relic part of the missing chamber, close to the margin of the pronounced umbilical boss. No umbilical openings, however, were found related to any previous chambers. We thus conclude that the species *C. parri* is correctly assigned to *Crespinella*, a genus having species with a very low trochospiral to planispiral coiling and one or more supplementary openings on the umbilical side.

Genus *Hofkerina* Chapman & Parr, 1931

Synonymy and Type species: see Loeblich & Tappan 1987, p. 551.

Remarks

Geographically *Hofkerina semiornata* (Fig. 5, 11, 12) is similar to *Almaena gippslandica*, as both are confined to the southeastern corner of southern continental margin (Carter 1958, 1964). *Almaena gippslandica* is an earliest Miocene form and apparently has affinities with species from Paratethys (see above), whereas *Hofkerina semiornata* seems to be entirely endemic to the region with a range from the early Miocene to early middle Miocene.

It is noteworthy that both *Hofkerina semiornata* and *Crespinella umbonifera*, above, have a similarly thick wall, which mimics the wall in the Eocene *Maslinella chapmani* (see below). Unlike *H. semiornata*, however, *C. umbonifera* and *M. chapmani*, have also been recorded from South Australia and Western Australia (Quilty 1980, 1981). It is not clear whether the thick wall in these endemic taxa signals a high $CaCO_3$ buildup in local waters during the warming phases of the later Eocene and early-middle Miocene.

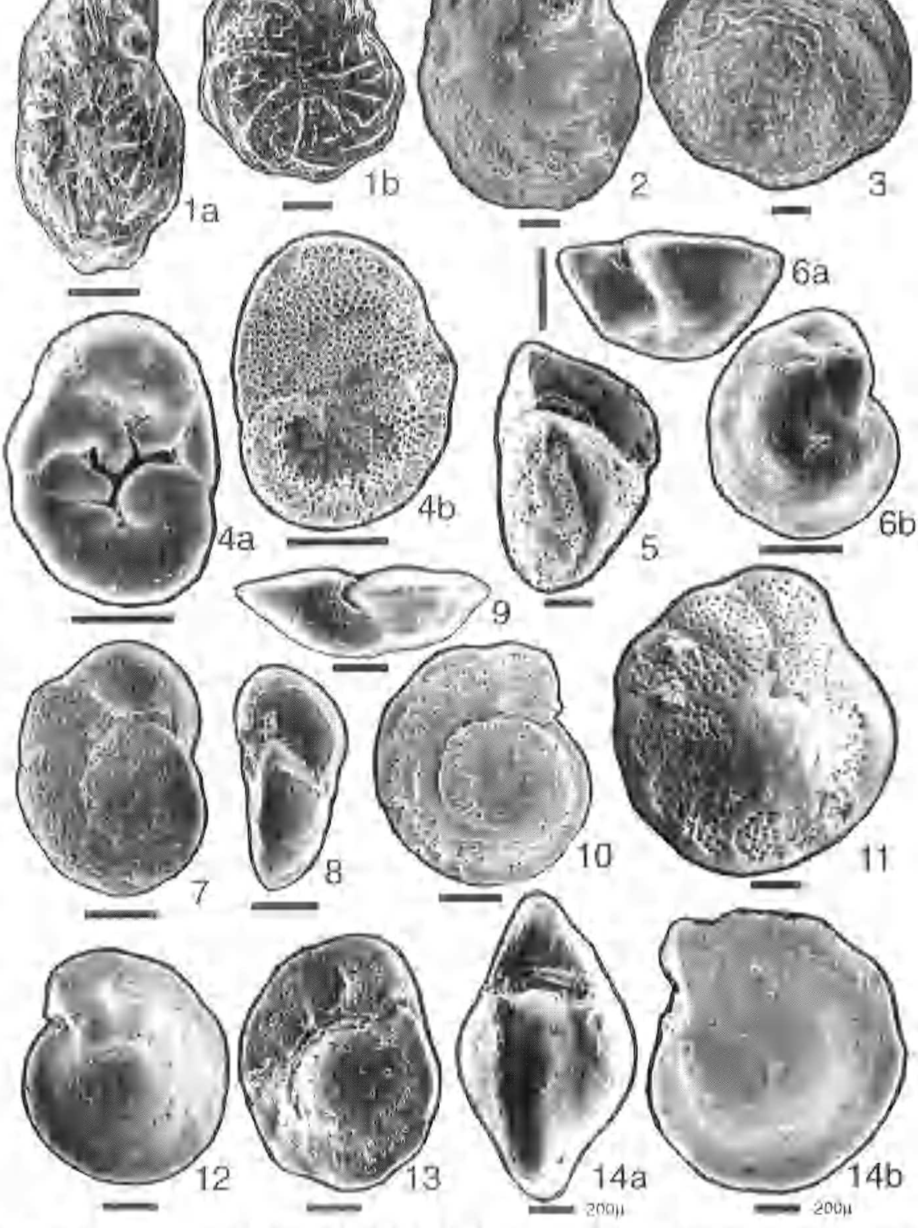

Fig. 4. Scale bar = 100 µm, unless otherwise indicated. 1a, b. *Almaena gippslandica* Carter: two views of a single specimen, latest Oligocene, Lakes Entrance, Sample 1156. 2, 3. *Asterigerinella adelaidensis* (Howchin): two specimens, later middle Eocene, Tortachilla Limestone, Maslin Bay, Sample AB-Tor. 4a, b. *Bronnimannia haliotis* (Heron-Allen & Earland): single specimen from the early middle Miocene, Cadell Marl section, Sample C9. 5. *Cibicides refulgens* de Montfort: Recent, Lacepede Shelf, Sample 89-1, water depth 171 m. 6a, b. *Cibicides vortex* Dorreen: single specimen, early Miocene, Lakes Entrance, Sample 808. 7, 8. *Cibicides ihungia* Finlay: two specimens, early Miocene, Lakes Entrance, Samples 992 and 732. 9, 10. *Cibicides mediocris* Finlay: two specimens, late Oligocene and early Miocene, Lakes Entrance, Samples 828 and 1196. 11. *Cibicidoides perforatus* (Karrer): late Eocene, Blanche Point Formation, Maslin Bay, Sample A3-091. 12, 13. *Cibicidoides pseudoungerianus* (Cushman): two specimens, late Oligocene and early Miocene, Lakes Entrance, Samples 1196 and 956. 14a, b. *Crespinella umbonifera*: two views of the uncoated holotype of ?*Operculina umbonifera* Howchin & Parr, using a Philips XL20 scanning electron microscope at the University of Adelaide (CEMMSA).

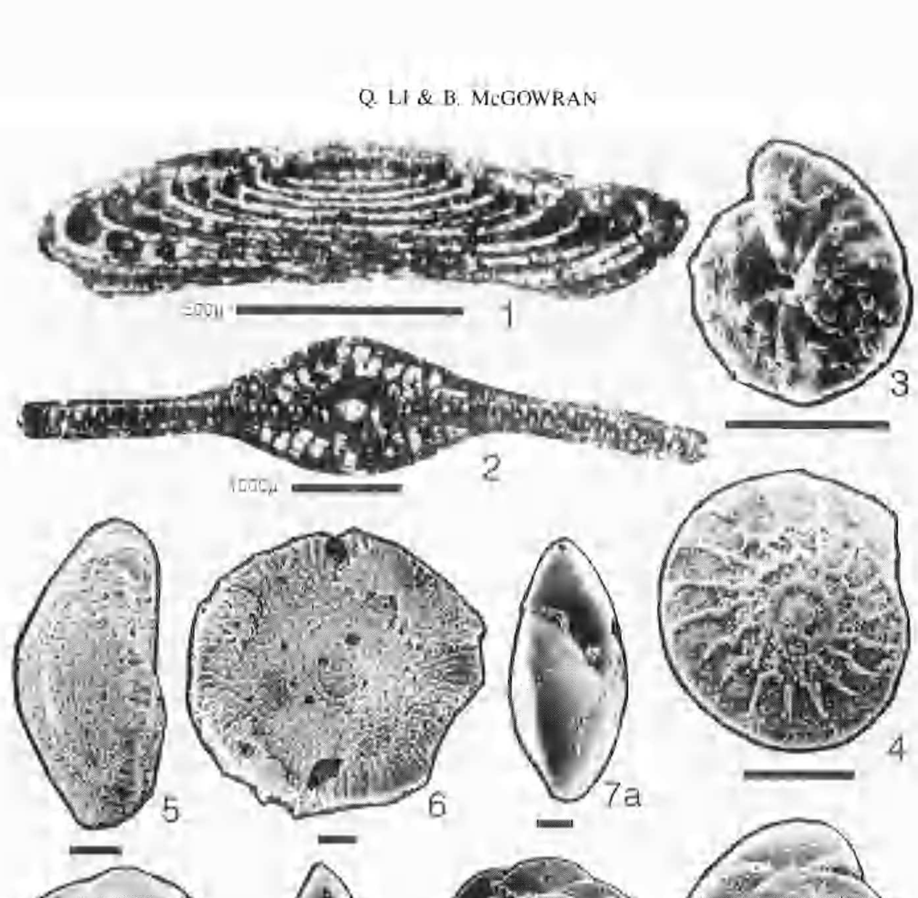

Fig. 5. Scale bar = 100 μm, unless otherwise indicated. 1. *Crespinina kingscotensis* Wade: axial section, early Oligocene, Port Vincent Limestone, Yorke Peninsula, Sample BSI. 2. *Lepidocyclina howchini* Chapman & Crespin: axial section, early middle Miocene, lower Morgan Limestone, Mannum, Sample Li/93-1. 3, 4. *Escornebovina cuvillieri* (Poignant): two specimens, earliest Oligocene, SADME bore A40, western Murray Basin (3), Ff 805, and SADME South Parklands Bore, Adelaide (4), Ff 808, both from Lindsay (1981[1], pl. 44, figs. 1, 3). Note that Lindsay[1], 1994 (pers. comm.) considered the form in no. 4 not a typical specimen of that species. 5, 6. *Halkyardia bartrumi* Parr: two specimens, late Eocene, Castle Cove, Sample RJFJ 19. 7a, b. *Heterolepa opaca* (Carter): single specimen, early Miocene, Lakes Entrance, Sample 724. 8-9. *Heterolepa brevoralis* (Carter): two specimens, early Miocene, Lakes Entrance, Samples 788 (8a, b) and 984 (9). 10a, b. *Heterolepa subhaidingeri* (Parr): single specimen, early Miocene, Lakes Entrance, Sample 852. 11, 12. *Hofkerina semiornata* (Howchin): two specimens, earliest Miocene, WMC 703, Samples 45.35 m and 45.65 m.

Family Chapmaninidae Thalmann, 1938
Genus *Crespinina* Wade, 1955

Synonymy and Type species: see Loeblich & Tappan 1987, p. 668.

Remarks

This genus, together with its only species *C. kingscotensis* (Fig. 5, 1), apparently represents one of the numerous taxa endemic to southern Australia. It has been recorded in South Australia (Wade 1955; Ludbrook 1961), Victoria (Carter 1958) and Western Australia (Quilty 1981). Quilty (1981) also noted that tests of *C. kingscotensis* became larger and more robust from east to west, indicating a warmer temperature towards the western part of the southern continental margin.

Crespinina kingscotensis occurs mainly in the later middle Eocene to early Oligocene (Wade 1955). In the Port Vincent Limestone from Yorke Peninsula (Fig. 1), it is associated with some planktonic foraminifera such as *Guembelitria*, an early Oligocene marker in local biostratigraphy (McGowran & Beecroft 1985), and its last appearance precedes the first appearance of *Amphistegina*. The latter datum in the region was within the late Oligocene (Lindsay 1985).

Family Gavelinellidae Hofker, 1956
Genus *Escornebovina* Butt, 1966

Synonymy and Type species: see Loeblich & Tappan 1987, p. 633.

Remarks

Specimens referable to *E. cuvillieri* were found in the basal Ettrick Formation (Oligocene) from the western Murray Basin and eastern St Vincent Basin (Lindsay 1981[1]), but this record has never been made public. These specimens were compared with the near-topotypes of *E. cuvillieri* from Escornebéou, France, supplied to Lindsay by Professor C. W. Drooger (Utrecht). This record thus extends the geographic distribution of this taxon from Paratethys to southern Australia.

Two of Lindsay's specimens are shown in Fig. 5, 3, 4.

Family Cymbaloporidae Cushman, 1927
Genus *Halkyardia* Heron-Allen & Earland, 1918

Synonymy and Type species: see Loeblich & Tappan 1987, p. 593.

Remarks

The conical *Halkyardia bartrumi* (Fig. 5, 5a, b) has been widely recorded in New Zealand from where it was originally named (Hornibrook *et al.* 1989). In southern Australia, Ludbrook (1961, as *Halkyardia* sp.) found similar forms in the western Murray Basin, and Quilty (1981) recorded it in the Nanarup Limestone near Albany, Western Australia (Fig. 1). On the eastern margin of the St Vincent Basin, this species makes two brief appearances, in the Tortachilla Limestone and the basal Port Willunga Formation (Lindsay 1967). McGowran *et al.* (1992) recently correlated these two intervals as from top P14 to early P15 in the later middle Eocene, and upper P18 in the early Oligocene respectively.

No record of this taxon has been reported to date from the eastern corner of southern Australia.

Family Heterolepidae Gonzáles-Donoso, 1969
Genus *Heterolepa* Franzenau, 1884

Synonymy and Type species: see Loeblich & Tappan 1987, p. 632.

Remarks

Many species of *Heterolepa* were previously recorded as *Cibicides* in southern Australia. The genus *Heterolepa* differs from the radially walled *Cibicides* in having a granular wall and an aperture which does not extend far onto the spiral side (Loeblich & Tappan 1987). *Cibicides brevoralis* (Fig. 5, 8-9), *C. opacus* (Fig. 5, 7a, b) and *C. subhaidingeri* (Fig. 5, 10a, b) all appear to have these features, and are accordingly transferred to the genus *Heterolepa*.

Also included in this genus is *Cibicides victoriensis* (see also Lindsay 1969, 1981[1]), a species confined to the middle Miocene, or Zones N9-N13 equivalents. Morphologically, *H. victoriensis* is similar to both *H. brevoralis* and *H. subhaidingeri*, but differs from the latter two in the strongly limbate sutures on the spiral side.

At the Morgan-Cadell section, western Murray Basin, *Heterolepa* decreases from the lower Morgan Limestone, disappears in the Cadell Marl, and reappears in the upper Morgan Limestone. The Cadell Marl is composed mainly of bioskeletons including abundant miliolid and discorbid foraminifera, and represents a restricted, but highly productive, environment. The marly sequence is dated at about 15 Ma, in the later part of the Miocene climatic optimum (Li & McGowran 1995). Its absence from the Cadell Marl indicates that *Heterolepa* may be an open marine genus only, in contrast to the ubiquitous *Cibicides*.

Family Lepidocyclindae Scheffen, 1932
Genus *Lepidocyclina* Gümbel, 1870

Synonymy and Type species: see Loeblich & Tappan 1987, p. 614.

Remarks

The last occurrence of *Lepidocyclina sensu lato* was

[1] Lindsay, J. M. (1981) Tertiary Stratigraphy and Foraminifera of the Adelaide City Area, St Vincent Basin, South Australia. Unpubl. M.Sc. Thesis, The University of Adelaide.

in the middle Miocene (Zone N9), if not the late Miocene or early Pliocene (Adams 1992). This has been apparently misquoted to be in the Aquitanian (N4, earliest Miocene) by Loeblich & Tappan (1987).

The local representative of this genus is *L. howchini* (Fig. 5, 2), a species widely reported from various localities in southern Australia (Ludbrook 1961; Lindsay 1969; Lindsay & Giles 1973; McGowran 1979; Quilty 1982; Chaproniere 1984; Lindsay 1985). Associated with many other larger forms, it was confined to the latest early Miocene to earliest middle Miocene, or Zones N8 and N9 equivalents. Its occurrence in the region has been hailed as a signal of the Miocene climatic optimum (McGowran 1979; Frakes *et al.* 1987; McGowran & Li 1993, 1995).

Family Linderinidae Loeblich & Tappan, 1984
Genus *Linderina* Schlumberger, 1893

Synonymy and Type species: see Loeblich & Tappan 1987, p. 645.

Remarks

The species *Linderina glaessneri* is large, discoid and internally complex with numerous chamberlets (Fig. 6, 1). Like *Halkyardia bartrumi*, above, it was restricted to the central and western parts of the region and has never been recorded from either Gippsland or Bass basins in the southeastern corner. The stratigraphical occurrence of *Linderina glaessneri* is also similar to that of *H. bartrumi* in two short intervals: later middle Eocene (Zones top P14-lower P15) and earliest Oligocene (upper P18). This record thus extends the range of that genus into the early Oligocene from the originally middle and late Eocene (Quilty 1981).

Family Elphidiidae Galloway, 1933
Genus *Parrellina* Thalmann, 1951

Synonymy and Type species: see Loeblich & Tappan 1987, p. 677.

Remarks

Wade (1957) emended *Parrellina*, a planispiral elphidiid which appears to have been restricted to southern Australian waters during its early evolutionary history. It first appeared in the middle Oligocene, Zone P21 equivalents, about 15 Ma after the evolution of its trochospiral ancestor *Notorotalia* Finlay.

The New Zealand taxon, *Discorotalia*, is similar to *Parrellina* in many morphological aspects except the distinct evolute spiral side, and both are believed to have evolved from the trochospiral *Notorotalia* (Eocene-Recent) in the late Oligocene. It is difficult, however, to separate *Parrellina* from *Discorotalia*, as some of our Oligocene-early Miocene specimens of *Parrellina crespinae* and *P.* cf. *imperatrix* tend to be also low-trochospiral (Fig. 6, 5-6). Typical planispiral *P. imperatrix* (Fig. 6, 7) seems to have occurred only from the early Miocene to Recent. Modern specimens of *P. imperatrix* from offshore southern Australia may grow a test > 1 mm in diameter, while its allied form *P. verriculata* is much smaller and without peripheral spines. A large, typically planispiral species existing in the early to middle Miocene (N6-N10) is *P. craticulatiformis* (Fig. 6, 8).

Family Siphoninidae Cushman, 1927
Genus *Siphoninoides* Cushman, 1927

Synonymy and Type species: see Loeblich & Tappan 1987, p. 572.

Remarks

A smooth form described by Howchin (1889) as *Truncatulina echinata* var. *laevigata* is apparently a *Siphoninoides* (Fig. 6, 4). Whether the smooth wall has been subject to the effect of cold waters is not known. This consistent feature guarantees that the taxon is a distinct species. The generic description of *Siphoninoides*, as in Loeblich & Tappan (1987), should be revised to embrace this feature.

We found numerous specimens of *S. laevigata* in samples from the Cadell Marl section, western Murray Basin (Fig. 1). The age of these samples is within Zones top N8 to N9 equivalents, early middle Miocene. Quilty (1994, pers. comm.) indicated that a similar form exists in the modern Swan River estuary, Western Australia.

Family Uvigerinidae Haeckel, 1894
Genus *Siphouvigerina* Parr, 1950

Synonymy and Type species: see Loeblich & Tappan 1987, p. 525.

Remarks

This genus was supposed to occur only in the Holocene (Loeblich & Tappan 1987). However, we recently discovered forms similar to the type species *S. fimbriata* from the Lakes Entrance section, Gippsland Basin, in a level correlated to the earliest Miocene. One of the specimens is illustrated in Fig. 6, 9). Our record thus extends the range of this genus down to the early Miocene, although the form was found only sporadically.

Revets (1993) recently found the type specimen of *S. fimbriata* to be biserial throughout, a finding contrasting the conventional definition of the genus (e.g. Parr 1950; Loeblich & Tappan 1987). However, many uvigerinid and angulogerinid forms are triserial initially and change to biserial at any later stage. The triserial part of the test would be difficult to define if early chambers are loosely coiled, a case most likely existing in *S. fimbriata*.

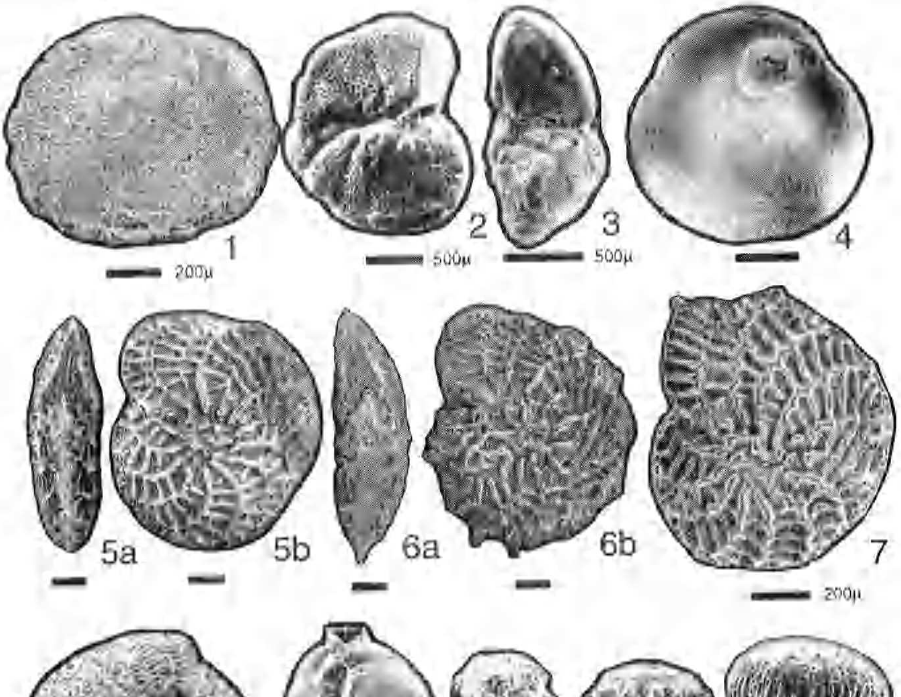

Fig. 6. Scale bar = 100 μm, unless otherwise indicated. 1. *Linderina glaessneri* Quilty: late Eocene, Castle Cove, Sample RJFI 19. 2, 3. *Maslinella chapmani* Glaessner & Wade: two specimens, late Eocene, Adelaide area (Children's Hospital), Sample 19.2-19.5 m, Ff 955 and Ff 956, both from Lindsay (1981', pl. 48, figs. 1, 4). 4. *Siphoninoides laevigatus* (Howchin): later early Miocene, Lower Morgan Limestone, Sample LM2. 5a, b. *Parrellina crespinae* Cushman: single specimen, earliest Miocene, Lakes Entrance, Sample 1140. 6a, b. *Parrellina* cf. *imperatrix* (Brady): single specimen, early Miocene, Lakes Entrance, Sample 992. 7. *Parrellina imperatrix* (Brady): Recent, Lacepede Shelf, Sample 89-60, water depth 82 m. 8. *Parrellina craticulatiformis* Wade: later early Miocene, Lower Morgan Limestone, Sample LM2. 9. *Siphogenerina fimbriata* (Sidebottom): earliest Miocene, Lakes Entrance, Sample 1140. 10. *Tubulogenerina ferox* (Heron-Allen & Earland): later early Miocene, Lakes Entrance, Sample 700. 11. *Tubulogenerina mooraboolensis* Cushman: later early Miocene, Lakes Entrance, Sample 868. 12. *Cifellia costata* (Heron-Allen & Earland): later early Miocene, Lakes Entrance, Sample 708. 13. *Victoriella conoidea* (Rutten): earliest Miocene, WMC 703, Sample 45.65 m. 14. *Wadella hamiltonensis* (Glaessner & Wade): late Eocene, Blanche Point Formation, Maslin Bay, Sample 099. 15a, b. *Parredicta kalimnensis* (Parr): single specimen, later middle Miocene, Lakes Entrance, Sample 416.

Family Siphogenerinoididae Saidova, 1981
Genus *Tubulogenerina* Cushman, 1927

Synonymy and Type species: see Loeblich & Tappan 1987, p. 520.

Remarks

Gibson (1987, 1989; Gibson *et al.* 1991) conducted a series of studies on the evolution and distribution of *Tubulogenerina* and related taxa. Two main conclusions from his studies are: (1) this genus ranged from early Eocene to Pliocene, with Europe being the site of its first evolution, and (2) species seem to have migrated westward from Europe, through the Atlantic, to Pacific and Indian Oceans. According to Gibson (1989), mid-latitude Miocene species were largely confined to the later early Miocene to early middle Miocene, or Zones N6 to N8 equivalents.

Quilty (1977) reported *T. mooraboolensis* from the early Miocene in Tasmania. In the Lakes Entrance oil shaft, we found three tubulogenerinines (Fig. 6, 10-12): *T. ferox*, *T. mooraboolensis* and *Cifellia costata*. The combined range of these species is from 263 m – 157 m in the section, which is mid-N5 to early N10 in our correlation (McGowran & Li 1993, 1995).

We follow Gibson (1989) in considering *C. costata* a tubulogenerinid without a toothplate. Revets (1991), however, classified *Cifellia* and *Tubulogenerina* into two different superfamilies, on the absence and occurrence of toothplates in these two genera respectively. Whether the toothplate ever exists in the early part of *C. costata* is not known, and little evidence has been found to resolve problems such as the development and reduction or function of foraminiferal toothplates (Revets 1993).

Family Victoriellidae Chapman & Crespin, 1930
Genus *Maslinella* Glaessner & Wade, 1959

Synonymy and Type species: see Loeblich & Tappan 1987, p. 596.

Remarks

Similar to several other endemic taxa, this genus is also monospecific. *Maslinella chapmani* (Fig. 6, 2, 3) is a large but internally simple form ranging from the later middle Eocene to earliest Oligocene. Although not mentioned in the original description, sutural openings occur on the umbilical side of some specimens (Fig. 6, 2), possibly resulting from relic apertural extensions. This feature can be seen even in the holotype, sketched in Fig. 3 (compare Glaessner & Wade 1959, pl. 1, fig. 7).

Crespinella parri Quilty, above, is morphologically similar to *Maslinella chapmani* at least in the following: (1) a large, low trochospiral test which tends to be planispiral in the final stage, (2) a distinct peripheral keel, (3) sutural openings on the umbilical side, and (4) a thick, laminated wall, though perforations on *M. chapmani* were much coarser. All these indicate that *C. parri* is morphologically, if not phylogenetically, closely related to *Maslinella*. The occurrence of *C. parri* in the late Oligocene is cryptogenic, and pending studies of its relationship with *M. chapmani* are necessary.

Genus *Victoriella* Chapman & Crespin, 1930

Synonymy and Type species: see Loeblich & Tappan 1987, p. 596.

Remarks

Glaessner & Wade (1959) emended this genus and discussed its affinities. They found the type species *Victoriella plecte* to be a junior synonym of *Carpenteria conoidea*, now *V. conoidea* (Rutten) (Fig. 6, 13). The total range of *V. conoidea* in southern Australia is from the latest Eocene (P17) to earliest Miocene (N4). Ludbrook (1971, p. 64) noted the transition of *V. conoidea* from *Carpenteria hamiltonensis* (now *Wadella hamiltonensis*, see below), in the earliest Oligocene *Globigerina angiporoides angiporoides* Zone.

The Eocene-Oligocene record of that species, however, is relatively rare. Only in the latest Oligocene and earliest Miocene did *V. conoidea* become common and southern Australia-wide, as well as from northeastern Australia (Quilty 1993). It is conspicuous in the carbonate-chert association of the Gambier Limestone in the Otway Basin (G. Moss, 1994, pers. comm.).

Genus *Wadella* Srinivasan, 1966

Synonymy and Type species: see Loeblich & Tappan 1987, p. 596.

Remarks

The genera *Wadella* and *Victoriella* are similarly large and high trochospiral. However, *Wadella hamiltonensis* (Fig. 6, 14) can be distinguished from *V. conoidea* by its smooth test lacking pillars and less regular coiling.

In the later middle to late Eocene, *Wadella hamiltonensis* was one of many large species endemic to southern Australia and New Zealand. Prior to the late Eocene, in southern Australia, *Wadella hamiltonensis* achieved a wider distribution than *V. conoidea* (Cooper 1979; Quilty 1981; Lindsay 1985). In the Maslin Bay section, *W. hamiltonensis* was found in the Tortachilla Limestone and basal Blanche Point Formation, in an interval equivalent to Zones upper P14 to P15 (McGowran *et al.* 1992). *Wadella globiformis* also evolved in the late Eocene, and ranged into the early Miocene. Unlike *W. hamiltonensis*, *W. globiformis* developed a low trochospiral test and globular chambers.

Family Bagginidae Cushman, 1927
Genus ***Parredicta*** gen. nov.
(FIG. 7)

Type species: Valvulineria porifera Parr, 1950

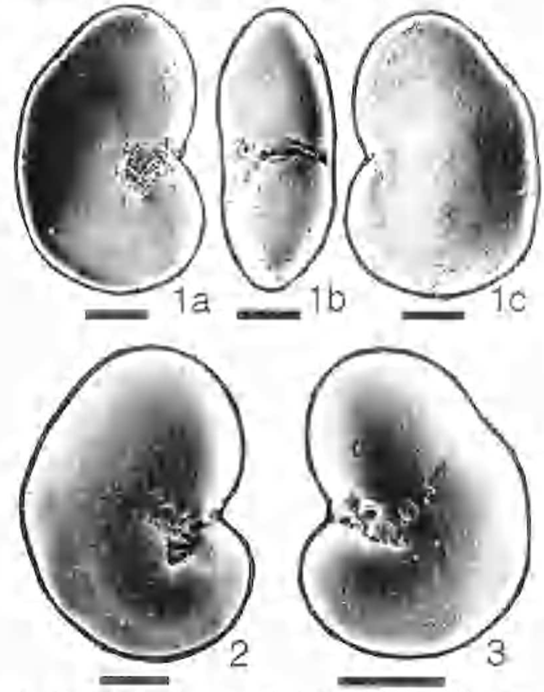

Fig. 7. *Parredicta porifera* (Parr). Scale bar = 200 μm. 1a-c. Scanning micrographs of the uncoated holotype of *Valvulineria porifera* Parr. 2, 3. Two specimens from Lacepede Shelf, Samples 89-3 and 89-1, in water depths 123 m (2) and 171 m (3) respectively.

Etymology

This genus is named in honour of W. J. Parr, who was one of the most influential and prolific foraminiferal students in southern Australia in the early part of this century, and who originally described the species on which this new genus is based; *edictum* (Latin) = proclamation or decree.

Description

Test medium to large, low trochospiral, biconvex; chambers high, enlarging regularly, more than 6 in the final whorl; 1½ to 2½ whorls in adult tests; surface smooth; sutures radiate to strongly curved, depressed or flush on ventral side, flush and limbate on the dorsal (spiral) side; umbilicus small, depressed or closed with shell material, but without a distinct umbilical boss; periphery narrowly rounded to weakly keeled; wall calcareous hyaline, distinctly perforate except a small area immediately above the apertural lip; aperture large, arched or slit-like, extending from periphery to marginal area of the umbilical depression; apertural lip distinct, regular or irregular; supplementary openings common, resulting from either irregular growth of the lip or relic extension of the aperture on the umbilical side.

Remarks

This genus differs from *Valvulineria* in having an oval test outline, angular periphery and supplementary openings, and lacking apertural flaps. *Valvulineria* Cushman has a pronounced apertural flap which projects over the umbilicus (Loeblich & Tappan 1987, p. 547). Many species of *Valvulineria* are rounded in outline, with a distinctly lobate margin which is broadly rounded in peripheral view, and have no supplementary openings on the umbilical side.

Parredicta is introduced to accommodate two species which were originally considered as *Planulina kalimnensis* Parr (Fig. 6, 15a, b) and *Valvulineria porifera* Parr (Fig. 7). Among others, Carter (1964) and Quilty (1980) recorded *Parredicta kalimnensis* (both as *Valvulineria kalimnensis*) in the Miocene of Victoria and Tasmania. In the Lakes Entrance oil shaft, it was found from 340 m to the top of sampling level (63.6 m), i.e. the earliest Miocene to late Miocene (Li & McGowran 1995). The younger occurrence of *P. kalimnensis* was reported by Quilty (1985) from the Pliocene in Flinders Island, Bass Strait. *Parredicta porifera* (Parr), on the other hand, seems to be a Quaternary species. On the Lacepede Shelf of South Australia, *P. porifera* occurs frequently between 50 m and 200 m, and some specimens grow up to about 1.5 mm (height) x 1 mm (width), with over 15 chambers in the final whorl (Li *et al.* 1995).

Quilty (1980) suggested that *Crespinella parri* was the probable ancestor of both *C. umbonifera* and *V. kalimnensis*. His view is upheld here. The evolution of this lineage might have begun from *C. parri* in the later Oligocene, but the radiation of both *Crespinella umbonifera* and *Parredicta kalimnensis* did not occur until the early Miocene. This was probably implemented by a morphological change from low trochospiral to planispiral (*C. parri* > *C. umbonifera*) and from keeled to weakly keeled or non-keeled (*M. parri* > *P. kalimnensis*). The loss of the umbilical filling (boss) also took place in the early Miocene and subsequently became a diagnostic feature in younger specimens of *P. kalimnensis* and, particularly, in the much younger *P. porifera* (Fig. 7).

Distribution

Southern Australia, early Miocene to Recent.

Acknowledgments

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Appendix 1. A list of genera and species

Almaena Samoylova
A. gippslandica Carter
Amphistegina d'Orbigny
Asterigerinella Bandy
A. gallowayi Bandy
A. adelaidensis (=*Truncatulina margaritifera* var. *adelaidensis* Howchin)
Bronnimannia Bermúdez
B. palmerae (=*Discorbis palmerae* Bermúdez)
B. haliotis (=*Discorbis haliotis* Heron-Allen & Earland)
Cifellia Gibson
C. costata (=*Chrysalidina costata* Heron-Allen & Earland)
Cibicides de Montfort
C. ihungia Finlay
C. mediocris Finlay
C. refulgens de Montfort
C. vortex Dorreen
Cibicidoides Thalmann
C. neoperforatus Hornibrook
C. perforatus (=*Rotalia perforata* Karrer)
C. pseudoungerianus =*Truncatulina pseudoungerianus* Cushman)
C. karreriformis Hornibrook
Crespinella Parr
C. parri Quilty
C. umbonifer (=?*Operculina umbonifera* Howchin & Parr)
Crespinina Wade
C. kingscotensis Wade
Discorotalia Hornibrook
Escornebovina Butt
E. cuvillieri (=*Rotalia cuvillieri* Poignant)
Halkyardia Heron-Allen & Earland
H. bartrumi Parr
Heterolepa Franzenau
H. brevoralis (=*Cibicides brevoralis* Carter)
H. opaca (=*Cibicides opacus* Carter)
H. subhaidingeri (=*C. subhaidingeri* Parr)
H. victoriensis (=*Cibicides victoriensis* Chapman, Parr & Collins)
Hofkerina Chapman & Parr
H. semiornata (=*Pulvinulina semiornata* Howchin)
Lepidocyclina Gümbel
L. howchini Chapman & Crespin
Linderina Schlumberger
L. glaessneri Quilty
Maslinella Glaessner & Wade
M. chapmani Glaessner & Wade
Notorotalia Finlay
Operculina d'Orbigny
Parredicta Li & McGowran
P. kalimnensis (=*Planulina kalimnensis* Parr)
P. porifera (=*Valvulineria porifera* Parr)
Parrellina Thalmann
P. craticulatiformis Wade
P. crespinae (=*Elphidium crespinae* Cushman)
P. imperatrix (=*Polystomella imperatrix* Brady)
P. verriculata (=*Polystomella vericulata* Brady)
Siphoninoides Cushman
S. laevigata (=*Truncatulina echinata* var. *laevigata* Howchin)
Siphouvigerina Parr
S. fimbriata (=*Uvigerina porrecta* var. *fimbriata* Sidebottom)
Tubulogenerina Cushman
T. ferox (=*Bigenerina ferox* Heron-Allen & Earland)
T. mooraboolensis Cushman
Victoriella Chapman & Crespin
V. conoidea (=*Carpenteria conoidea* Rutten)
Victoriella plecte (=*Carpenteria proteiformis* var. *plecte* Chapman)
Wadella Srinivasan
W. hamiltonensis (=*Carpenteria hamiltonensis* Glaessner & Wade)
W. globiformis (=*Carpenteria globiformis* Chapman)